

LATHAM & WATKINS LLP

April 5, 2017

Marlene H. Dortch
Secretary
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Re: ViaSat, Inc., U.S. WP 4A Preparations; GN Docket No. 14-177; IB
Docket Nos. 15-256 & 97-95; RM-11664; WT Docket No. 10-112

Dear Ms. Dortch:

As part of U.S. WP 4A Preparations, ViaSat, on its own and with other U.S. satellite network operators, has recently met with various member of the Office of Engineering and Technology, Wireless Telecommunications Bureau, and the International Bureau, and Erin McGrath, Legal Advisor, Commissioner O’Rielly’s Office. The discussions addressed satellite and earth station protection criteria in the Ka and V bands in the context of U.S. preparations for the upcoming International Telecommunications Union (ITU) Radiocommunication Bureau, Study Group 4 (Satellite Services), Working Party 4A (Efficient orbit/spectrum utilization for the fixed-satellite service (FSS) and broadcasting-satellite service (BSS)) meeting in Geneva from May 3-12, 2017.

The attached combined presentation was used to provide the Commission with background and insight into the appropriate protection criteria for FSS satellite networks in the V band under study in conjunction with potential 5G/IMT deployment in the V band.

To ensure the completeness of the record in the *Spectrum Frontiers* proceeding, the enclosed materials are provided here for inclusion in the record of that rulemaking.

The presentation covers:

- Current satellite link budgets.
- Current satellite coding, modulation, and spectral efficiency.
- Impact of increased thermal noise (Interference) on satellite throughput/capacity.

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- Irrelevance of the 0.1% rule to developing satellite receiver interference protection criteria.

And concludes that:

- Current-generation satellite modems use highly efficient DVB-S2x or similar modulation schemes.
- Links can go from quasi-error free to unusable within a few tenths of a dB of degradation.
- Satellite links currently designed are based on -12.2 dB I/N from all other co-primary sources.
- The record in *Spectrum Frontiers* proceeding demonstrates that the Commission and the 5G industry believe 5G operation without constraint is possible, while still meeting -12.2 dB I/N criteria.

Please contact the undersigned if you have any questions regarding this submission.

Respectfully submitted,

/s/

John P. Janka

Attachment

cc: Rachel Bender
Erin McGrath
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Protection Criteria

FCC Meeting

[3-29-2017]

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- A vertical decorative strip on the left side of the slide, featuring a collage of images: a satellite dish, a person in a military helmet, and a family (a man, a woman, and a child) smiling. The strip is semi-transparent and runs the full height of the slide.
- Current satellite link budgets
 - Current satellite coding, modulation, and spectral efficiency
 - Impact of increased thermal noise (Interference) on satellite throughput/capacity
 - Irrelevance of the 0.1% rule to developing satellite receiver interference protection criteria

■ ViaSat satellite links are not limited by self interference from other beams within its frequency reuse scheme

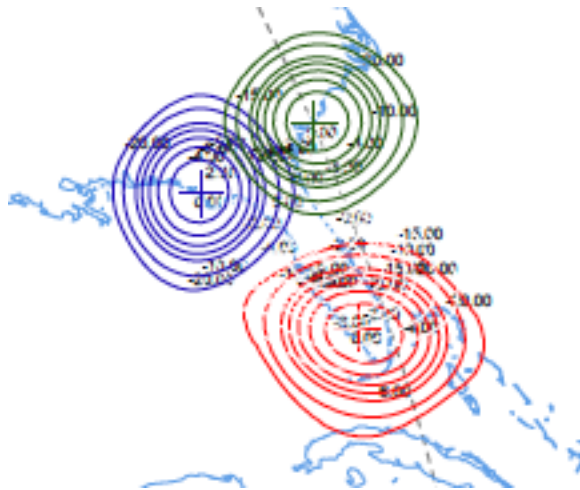
- ◆ Thermal noise remains the largest contributor
- ◆ Links are C/N dominated, not C/I limited
- ◆ Various frequency reuse schemes are used by ViaSat
 - Some schemes greatly reduce or eliminate inter-beam interference
- ◆ ViaSat-1 1st Gen design is more limited in terms of inter-beam interference than later designs
- ◆ ViaSat-1 Examples follow
 - Beam 60 South Florida
 - Beam 72 Southern California
 - Beam 58 Denver
 - Beam 61 Hawaii
 - Beam 57 Alaska

ViaSat-1 Examples

ViaSat

■ South Florida – Beam 60

- ◆ No overlapping co-frequency user or gateway beams



Link Budget

■ Florida Beam 60

- ◆ 13.58 dB Es/No – 12.73 dB C/(N+I) = 0.85 dB total interference without 5G present
- ◆ See sidebar for additional C/(N+I) impact when 5G I/N of various levels is added

Uplink	Value	Units
Terminal EIRP Capability	49.50	dBW
UL Es/No Target	13.583	dB
EIRP/RBd	37.63	dBW/MBd
Clear Sky Symbol Rate	10.00	MBd
Clear Sky EIRP	47.63	dBW
Reserve EIRP	1.88	dB
Uplink Frequency	29.75	GHz
Elevation Angle	41.33	°
Slant Range	37,679	km
Power Flux at Satellite	-117.39	dBW/m²
Free Space Path Loss	213.43	dB
Nominal Additional Losses	1.50	dB
Cloud and Rain Attenuation	0.00	dB
UT Pointing Error Loss	1.00	dB
Total Losses	215.93	dB
Satellite G/T	23.29	dB/K
C/No - Uplink	83.58	dB-Hz
Es/No - Uplink	13.58	dB
C/I - from Users	29.12	dB
C/I - from GW's	39.83	dB
C/I - Total Uplink	28.77	dB
Adjacent Satellite C/I - Uplink	31.00	dB
C/I - Other	21.31	dB
C/(N+I) - Uplink	12.73	dB

$$C/I \text{ 5G} = E_s/N_o - 5G \text{ I/N}$$

$$C/(N+I_{\text{tot}}) =$$

$$-10 \log(10^{(-C/I_1/10)} + 10^{(-C/I_2/10)} + \dots 10^{(-C/I_x/10)})$$

5G impact to C/(N+I_{tot}):

0.21 dB additional when 5G I/N = -12.2 dB

0.34 dB additional when 5G I/N = -10 dB

0.81 dB additional when 5G I/N = -6 dB

2.60 dB additional when 5G I/N = 0 dB

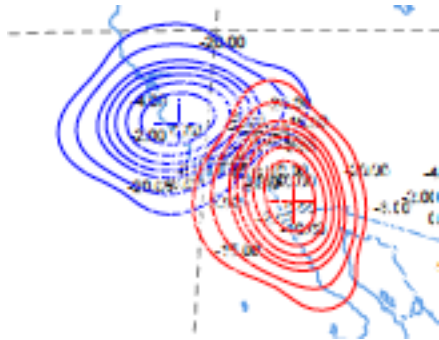
Clearly 5G has an impact over and above other satellite link impairments

ViaSat-1 Examples



■ Southern California – Beam 72

- ◆ Nearest co-frequency user beam 20 dB down at -5 dB contour – typical edge of service for the beam



Link Budget

■ So California Beam 72

- ◆ 10.60 dB Es/No – 9.08 dB C/(N+I) = 1.52 dB total interference without 5G present
- ◆ See sidebar for additional C/(N+I) impact when 5G I/N of various levels is added

Uplink	Value	Units
Terminal EIRP Capability	49.50	dBW
UL Es/No Target	10.600	dB
EIRP/RBd	35.51	dBW/MBd
Clear Sky Symbol Rate	20.00	MBd
Clear Sky EIRP	48.52	dBW
Reserve EIRP	0.98	dB
Uplink Frequency	29.75	GHz
Elevation Angle	51.54	°
Slant Range	36,983	km
Power Flux at Satellite	-116.33	dBW/m ²
Free Space Path Loss	213.27	dB
Nominal Additional Losses	1.50	dB
Cloud and Rain Attenuation	0.00	dB
UT Pointing Error Loss	1.00	dB
Total Losses	215.77	dB
Satellite G/T	22.26	dB/K
C/No - Uplink	83.61	dB-Hz
Es/No - Uplink	10.60	dB
C/I - from Users	16.76	dB
C/I - from GW's	21.37	dB
C/I - Total Uplink	15.47	dB
Adjacent Satellite C/I - Uplink	31.00	dB
C/I - Other	21.31	dB
C/(N+I) - Uplink	9.08	dB

$$C/I \text{ 5G} = E_s/N_o - 5G \text{ I/N}$$

$$C/(N+I_{\text{tot}}) =$$

$$-10 \log(10^{(-C/I_1/10)} + 10^{(-C/I_2/10)} + \dots 10^{(-C/I_x/10)})$$

5G impact to C/(N+I_{tot}):

0.18 dB additional when 5G I/N = -12.2 dB

0.30 dB additional when 5G I/N = -10 dB

0.71 dB additional when 5G I/N = -6 dB

2.32 dB additional when 5G I/N = 0 dB

Clearly 5G has an impact over and above other satellite link impairments

ViaSat-1 Examples



■ Denver, Hawaii, and Alaska beams

- ◆ No adjacent user beams
- ◆ Only co-frequency beam near by is a gateway beam operating in cross-pol



Link Budget

■ Denver Beam 58

- ◆ 10.26 dB Es/No – 8.24 dB C/(N+I) = 2.01 dB total interference without 5G present
- ◆ See sidebar for additional C/(N+I) impact when 5G I/N of various levels is added

Uplink	Value	Units
Terminal EIRP Capability	49.50	dBW
UL Es/No Target	10.260	dB
EIRP/RBd	33.19	dBW/MBd
Clear Sky Symbol Rate	20.00	MBd
Clear Sky EIRP	46.20	dBW
Reserve EIRP	3.31	dB
Uplink Frequency	29.75	GHz
Elevation Angle	42.82	°
Slant Range	37,568	km
Power Flux at Satellite	-118.79	dBW/m ²
Free Space Path Loss	213.41	dB
Nominal Additional Losses	1.50	dB
Cloud and Rain Attenuation	0.00	dB
UT Pointing Error Loss	1.00	dB
Total Losses	215.91	dB
Satellite G/T	24.38	dB/K
C/No - Uplink	83.27	dB-Hz
Es/No - Uplink	10.26	dB
C/I - from Users	26.79	dB
C/I - from GW's	13.44	dB
C/I - Total Uplink	13.24	dB
Adjacent Satellite C/I - Uplink	31.00	dB
C/I - Other	21.31	dB
C/(N+I) - Uplink	8.24	dB

$$C/I_{5G} = E_s/N_o - 5G \text{ I/N}$$

$$C/(N+I_{tot}) =$$

$$-10 \log(10^{(-C/I_{1/10})} + 10^{(-C/I_{2/10})} + \dots 10^{(-C/I_{x/10})})$$

5G impact to C/(N+I_{tot}):

0.16 dB additional when 5G I/N = -12.2 dB

0.26 dB additional when 5G I/N = -10 dB

0.64 dB additional when 5G I/N = -6 dB

2.12 dB additional when 5G I/N = 0 dB

Clearly 5G has an impact over and above other satellite link impairments

Link Budget

■ Hawaii Beam 61

- ◆ 8.97 dB Es/No – 8.26 dB C/(N+I) = 0.71 dB total interference without 5G present
- ◆ See sidebar for additional C/(N+I) impact when 5G I/N of various levels is added

Uplink	Value	Units
Terminal EIRP Capability	49.50	dBW
UL Es/No Target	8.974	dB
EIRP/RBd	37.59	dBW/MBd
Clear Sky Symbol Rate	10.00	MBd
Clear Sky EIRP	47.59	dBW
Reserve EIRP	1.91	dB
Uplink Frequency	29.75	GHz
Elevation Angle	37.86	°
Slant Range	37,948	km
Power Flux at Satellite	-117.49	dBW/m²
Free Space Path Loss	213.49	dB
Nominal Additional Losses	1.50	dB
Cloud and Rain Attenuation	0.00	dB
UT Pointing Error Loss	1.00	dB
Total Losses	215.99	dB
Satellite G/T	18.78	dB/K
C/No - Uplink	78.97	dB-Hz
Es/No - Uplink	8.97	dB
C/I - from Users	56.96	dB
C/I - from GW's	18.42	dB
C/I - Total Uplink	18.42	dB
Adjacent Satellite C/I - Uplink	31.00	dB
C/I - Other	21.31	dB
C/(N+I) - Uplink	8.26	dB

$$C/I_{5G} = E_s/N_o - 5G \text{ I/N}$$

$$C/(N+I_{tot}) =$$

$$-10 \log(10^{(-C/I_{1/10})} + 10^{(-C/I_{2/10})} + \dots 10^{(-C/I_{x/10})})$$

5G impact to C/(N+I_{tot}):

0.22 dB additional when 5G I/N = -12.2 dB

0.35 dB additional when 5G I/N = -10 dB

0.85 dB additional when 5G I/N = -6 dB

2.67 dB additional when 5G I/N = 0 dB

Clearly 5G has an impact over and above other satellite link impairments

Link Budget

■ Alaska Beam 57

- ◆ 10.28 dB Es/No – 9.04 dB C/(N+I) = 1.24 dB total interference without 5G present
- ◆ See sidebar for additional C/(N+I) impact when 5G I/N of various levels is added

Uplink	Value	Units
Terminal EIRP Capability	49.16	dBW
UL Es/No Target	10.277	dB
EIRP/RBd	36.12	dBW/MBd
Clear Sky Symbol Rate	20.00	MBd
Clear Sky EIRP	49.13	dBW
Reserve EIRP	0.03	dB
Uplink Frequency	28.60	GHz
Elevation Angle	13.05	°
Slant Range	40,264	km
Power Flux at Satellite	-116.46	dBW/m ²
Free Space Path Loss	213.67	dB
Nominal Additional Losses	1.50	dB
Cloud and Rain Attenuation	0.00	dB
UT Pointing Error Loss	1.00	dB
Total Losses	216.17	dB
Satellite G/T	21.72	dB/K
C/No - Uplink	83.29	dB-Hz
Es/No - Uplink	10.28	dB
C/I - from Users	33.27	dB
C/I - from GW's	16.50	dB
C/I - Total Uplink	16.41	dB
Adjacent Satellite C/I - Uplink	31.00	dB
C/I - Other	21.31	dB
C/(N+I) - Uplink	9.04	dB

$$C/I \text{ 5G} = E_s/N_o - 5G \text{ I/N}$$

$$C/(N+I_{\text{tot}}) =$$

$$-10 \log(10^{(-C/I_1/10)} + 10^{(-C/I_2/10)} + \dots 10^{(-C/I_x/10)})$$

5G impact to C/(N+I_{tot}):

0.19 dB additional when 5G I/N = -12.2 dB

0.31 dB additional when 5G I/N = -10 dB

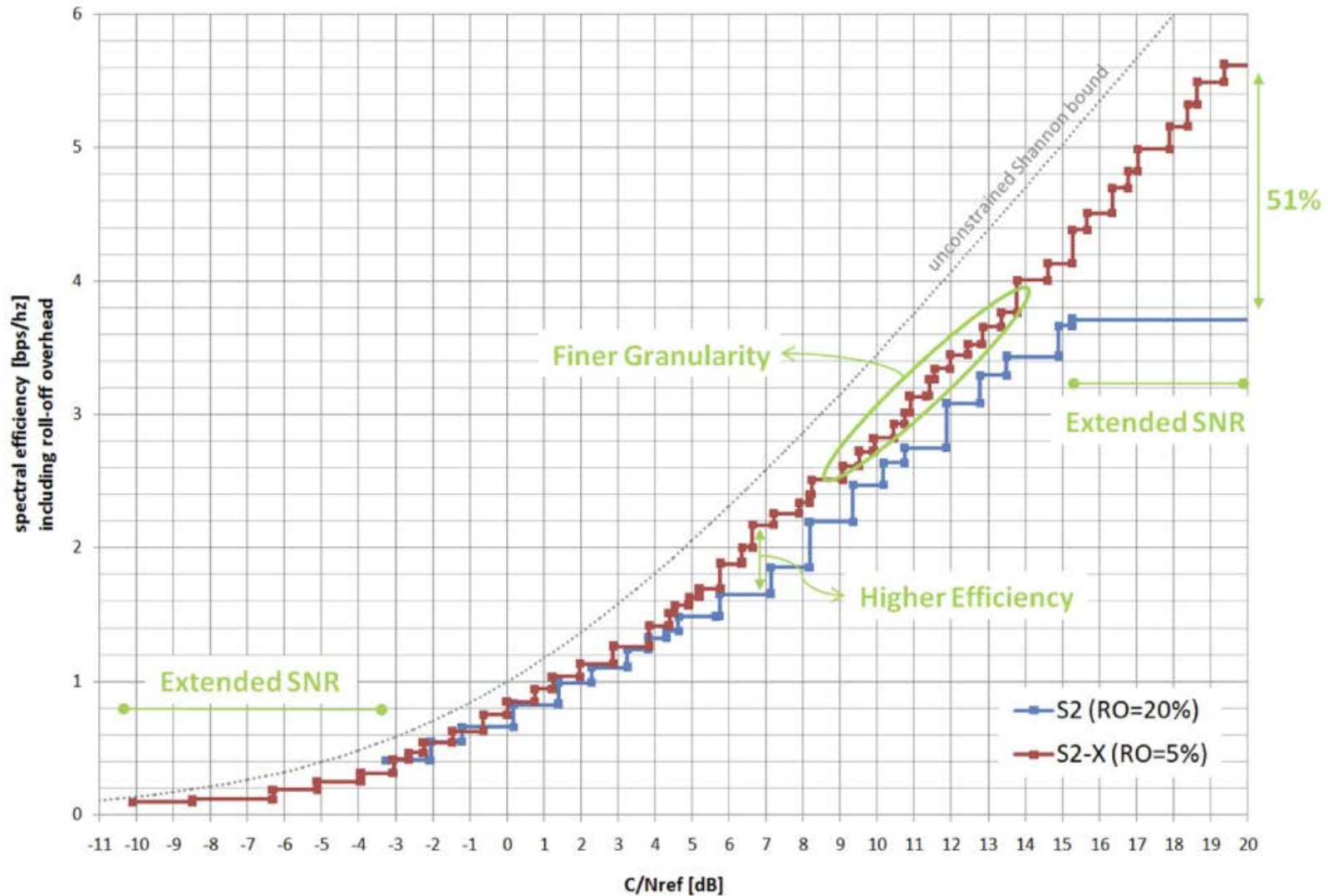
0.75 dB additional when 5G I/N = -6 dB

2.43 dB additional when 5G I/N = 0 dB

Clearly 5G has an impact over and above other satellite link impairments

DVB-S2(x) MODCODE Spectral Efficiency

ViaSat



DVB Fact Sheet - August 2016

[//www.dvb.org/resources/public/factsheets/dvb-s2x_factsheet.pdf](http://www.dvb.org/resources/public/factsheets/dvb-s2x_factsheet.pdf)

Thermal Noise Impact on ACM

$\Delta T/T$	I/N [dB]	$\Delta(N+I)$ [dB]
6%	-12.2	0.25
10%	-10.0	0.41
25%	-6.0	0.97

Start MODCODE	Received Es/NO [dB]	Thermal Noise Increase [dB]	Received Es/NO with Increased Noise [dB]	New MODCODE	Percent Capacity Loss
QPSK 1/2	0.6	0.25	0.35	QPSK 4/9	16%
QPSK 1/2	0.6	0.41	0.19	QPSK 14/15	38%
QPSK 1/2	0.6	0.97	-0.37	QPSK 14/15	38%
16APSK 2/3	8.43	0.25	8.18	16APSK 3/5	10%
16APSK 2/3	8.43	0.41	8.02	16APSK 3/5	10%
16APSK 2/3	8.43	0.97	7.46	8PSK 13/18	23%

Genesis of -77.6 dBm/m²/MHz PFD

- **FCC first proposed 47 dBuV/m as a “coordination and field strength limit at market borders”**
 - ◆ Based on Part 27 rules
 - ◆ No reference bandwidth was given
 - ◆ See SF NPRM at paras 289-90

- **ViaSat calculated 28 GHz “compatibility zones” for earth stations and 5G networks based on NPRM’s proposed 5G coordination threshold**
 - ◆ Simply converted field strength into a PFD of -106.16 dBW/(m²*MHz) – same as -76.16 dBm/(m²*MHz)
 - Using specified 5.5 MHz channel bandwidth in Part 27
 - ◆ Since no 5G performance data was available
 - Did not convert this PFD level into an equivalent I/N
 - Did not opine on suitable 5G I/N levels
 - ◆ Calculation was based on proposal for continued satellite uses not being subordinate to new 5G uses
 - ◆ See January 28, 2016 ViaSat comments at Ex. 1

Genesis of -77.6 dBm/m²/MHz PFD



- **5G proponents first endorsed -77.6 dBm(m²*MHz) PFD at 200 m as adequate to protect 5G in a May 6, 2016 ex parte**
 - ◆ Endorsement based on 5G proponents' claimed "reasonable protection margin of -6 dB I/N"
 - "the distance where less than 5% of links fall below the protection threshold (the criteria used to establish the cell edge for purposes of 3GPP calculations)"
 - ◆ See joint Nokia, AT&T, Verizon, Samsung & T-Mobile May 6, 2016 ex parte letter at 4 & Att.1
 - ◆ Referenced in June 1, 2016 joint Nokia, AT&T, Verizon, Samsung & T-Mobile ex parte letter at 1
- **Verizon endorsed -77.6 dBm(m²*MHz) PFD at 200 m as a component of its proposed "0.1% Rule"**
 - ◆ See Verizon June 14, 2016 ex parte letter at 1 (citing June 1 joint 5G filing)

The “0.1% Rule” Produces a Negligible I/N Contribution



- The FCC’s adopted “0.1% Rule” is similar in many respects to the Verizon proposal
 - ◆ Actual $-77.6 \text{ dBm}(\text{m}^2 \cdot \text{MHz})$ PFD at 200 m generated by earth stations is a critical component
- Any I/N into 5G from satellite under the 0.1% Rule would be very limited
 - ◆ Can occur only
 - If it also affects no more than 0.1% of the population in a county
 - Away from major event venues, arterial streets, interstates, U.S. highways, urban mass transit routes, passenger railroads, cruise ship ports
 - ◆ Specifically designed to affect (at most) a negligible percentage of 5G links, i.e., I/N for majority of links is $\ll -12.2 \text{ dB}$
- Any additional satellite uses are on a secondary, non-interference basis
- Any satellite contribution into I/N for 28 GHz 5G would have miniscule impact on overall 5G network capacity

Conclusions

- **Current-generation satellite modems use highly efficient DVB-S2x or similar modulation schemes. As a result links can go from quasi-error free to unusable within a few tenths of a dB of degradation.**
 - ◆ Requires a step down to lower MODCOD point or symbol rate to accommodate reduced E_s/N_0 , at the cost of reduced throughput
- **Satellite links currently designed based on -12.2 dB I/N from all other co-Primary sources**
 - ◆ While not always achievable, design approach maximizes throughput in a manner consistent with long-standing international standards and practices
 - ◆ Use of -10 dB I/N would result in a 2% capacity reduction over -12.2 dB I/N on average over VS-1 coverage
 - ◆ Select cases operating near MODCOD threshold point may experience higher capacity reduction some of the time

Conclusions Continued

- Record in SF Proceeding demonstrates that FCC and 5G industry believes operation without constraint is possible, while still meeting -12.2 dB I/N criteria

- ◆ No studies yet on the record demonstrating otherwise

- Report and Order text (para 294):

- ◆ *"Discussion.* The analyses provided by commenters leads us to conclude that specific technical limits on UMFUS stations are not necessary at this time to address aggregate interference. As discussed in more detail below, the information in the record shows a wide disparity between assumptions and illustrates that much work must be done to accurately model mmW systems and the effects that these systems might have on co-channel satellite receivers. As a result, we do not want to unduly restrict the development and growth of UMFUS unless we have adequate evidence that actual harm will occur. We do not believe the record demonstrates that there is a risk of interference to satellites from aggregate interference caused by UMFUS stations. Consequently, we will not adopt a limit on aggregate skyward interference from 28 GHz band UMFUS stations or require that UMFUS stations employ specific techniques to reduce skyward emissions."